

***Highway Rehabilitation Integrating  
Pavement, Construction, and Traffic***

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**CA4PRS Software V1.0**  
*(Construction Analysis for  
Pavement Rehabilitation Strategies)*

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**CA4PRS Agenda**

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- **CA4PRS Development**
- **CA4PRS Analysis Process**
- **CA4PRS Modeling**
- **CA4PRS Pilot Projects**
- **CA4PRS Outreach Efforts**
- **Discussion**

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# CA4PRS Development

## **Why Was CA4PRS Developed?**

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- To quickly calculate construction productivity for Long-Life Pavement Rehabilitation Strategies (LLPRS) closures
- To identify the most important variables constraining productivity in extended closures (longer than 7-10 hr nighttime closures)
- To provide quantitative comparison of duration of alternative closure strategies for integration with planning, traffic, and pavement analyses

## Integration Need for Long-life Pavement Rehabilitation

- Balance Conflicting Objectives: Long-life Design with Fast Construction and Minimum Traffic Delay
- Pavement Design
  - Structural sections to meet design life
  - Faster materials
  - Reduce thickness by increasing construction quality
- Construction Logistics
  - Fast-track construction, around the clock operations
  - Contracting and Project delivery: A+B+C+I/D+PF
  - Planning of Logistics, Resources, and Site Access
- Traffic Operations
  - Road user cost evaluation and congestion mitigation plan
  - Work-zone Information Systems and public outreach

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## CA4PRS Capability for LLPRS Projects

- Models Accelerated Rehabilitation Process
- Analyze a **maximum distance** of rehabilitation
- Estimate closure numbers and project duration
- Decision-making tool for LLPRS projects
  - Evaluate “What-if” rehabilitation strategies
  - Develop Plans: Design/Construction/Traffic
  - Check Construction Staging: Resident Engineer
  - Review Constructability of rehabilitation alternatives
- Establish Construction baseline for Integration of Pavement design, Construction logistics, and Traffic operations

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## **Funding Supports for CA4PRS Software Development**

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- **1999-2001**: Caltrans PPRC (DRI) for Modeling & Prototype Spreadsheet (\$200,000)
- **2001-2002**: FHWA Pooled-fund SPR-3(098) to code software (\$200,000)
  - **4-State DOT(CA-MN-TX-WA) Pavement Technology Consortium (SPTC)**
- **1999-2003**: FHWA/ACPA/NAPA Funds for Case Studies (\$130,000)
- **2001-2003**: PPRC (DRI) Funding for Case Studies and Associated Traffic Studies (\$200,000)
- **2002-2003**: Fund for I-15 (D8) Implementation (\$200,000)

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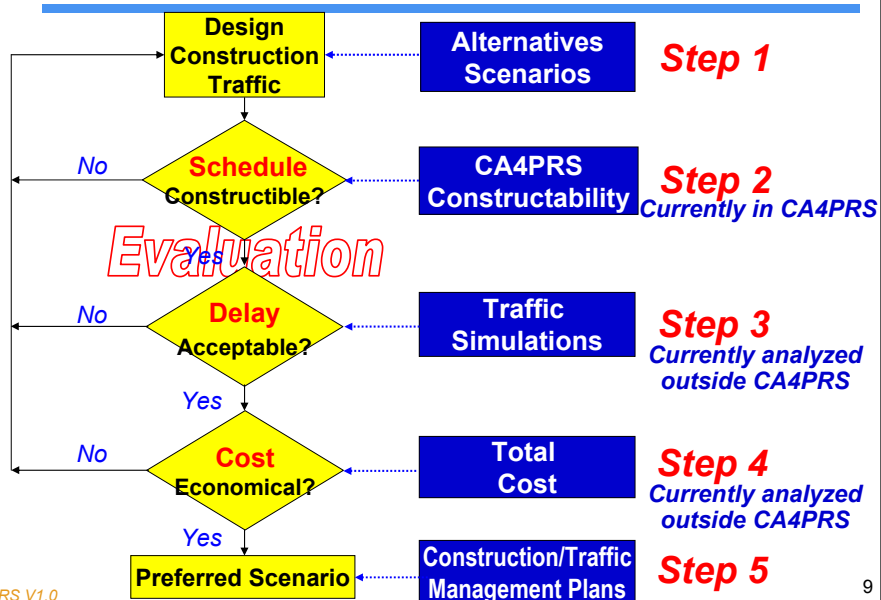
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## **CA4PRS Analysis Process**

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## Selection Process for the Most Economic Rehabilitation Scenario



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## Step 1: CA4PRS V1.0 Main Inputs Create Alternative Scenarios

- **Pavement Design**
  - Rehabilitation Strategy Alternatives
  - Design (Cross-section) Alternatives
  - Materials Alternatives
- **Traffic Control & Operations**
  - Construction Widows (Closure timing)
  - Lane Closure Alternatives
- **Construction Logistics and Constraints**
  - Activity Lead-lag relationships
  - Construction Resources Logistics
  - Weather Condition (AC Cooling time)

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## Step 2: CA4PRS Constructability Schedule Analysis Outputs

- **CA4PRS Outputs**
  - Maximum Rehabilitation Production (lane-km)
  - Total Number of Construction Closures
  - Total Closure Durations
  - Parameters Sensitivity
- **Constructability Analysis**
  - Compares Mix, Base type, and Widened Truck lane
  - Evaluate Construction Schedule Benefits
- **CA4PRS Outputs => Inputs to Traffic Analysis**
  - CA4PRS 1.0 Run Traffic Analysis *Separately*
  - Demand-Capacity Model (HCM) Spreadsheet Developed
  - Version 2.0 will have the Embedded Traffic Module

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## Step 3: Traffic Delay Analysis Road User Cost + Maximum Delay

- **Incorporated Traffic Analysis Tools**
  - Highway Capacity Manual (Spreadsheet)
  - Macro Simulation: FREQ
  - Microscopic Simulation: Paramics
- **Needed Additional Traffic Information**
  - Geometry: Nodes, Links, Lane numbers, Traffic Control
  - Demand: Hourly & Daily Counts, Truck percentage
  - Capacity: Construction Workzone Capacity
  - Traffic Demand Control: Reduction (No-show + Detours)
- **Traffic Analysis Outputs**
  - Total Road User Cost (RUC)
  - Maximum Delay per Closure
  - Demand Sensitivity

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## **Step 4: Economic Analysis**

### **Total Cost = Agency + Road User Costs**

- **Comparison of Alternative Scenarios**
  - Select the Most Economical Rehabilitation Scenarios
- **Total Cost: Economic Analysis**
  - Total cost = RUC + Agency cost
  - Agency Cost = Construction + Traffic Handling
  - Apply a Discount Factor for Road User Cost
- **Other Qualitative Aspects**
  - Pavement Life Expectancy: LCCA
  - Environmental Aspects
  - Public Perception
  - Impact on Local Business

## **Step 5: Preferred Scenario**

### **Construction & Traffic Management Plans**

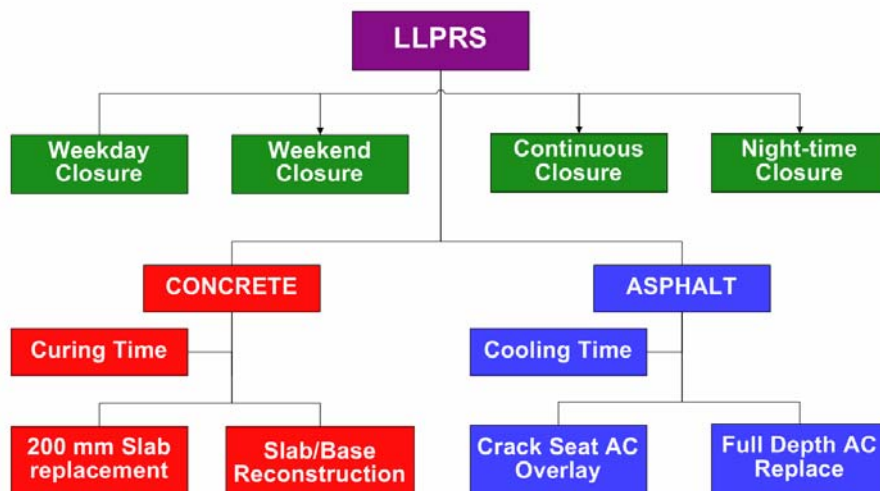
- **Construction Management Plan**
  - Rehabilitation Scope and Process
  - CPM Schedule
  - Contingency Plan
  - Incentives and “A + B” (Cost/Schedule) Contract
- **Traffic Management Plan**
  - (Automatic) Workzone Information Systems
  - Detour Plans
  - Public Outreach: Demand Reduction
  - Lane Closure Charts: Lane, Ramp, Connector
- **Implement Public Outreach**

# CA4PRS Modeling

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## CA4PRS Analysis Hierarchy

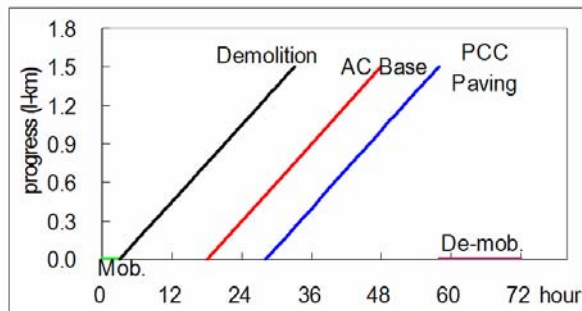
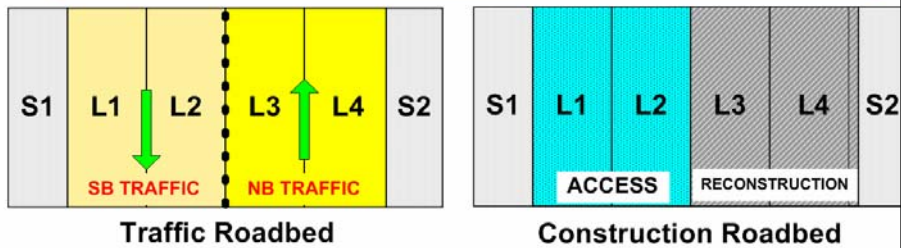


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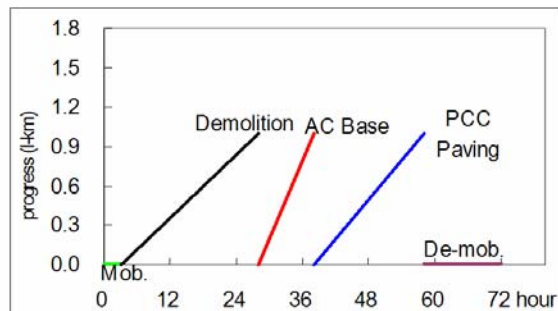
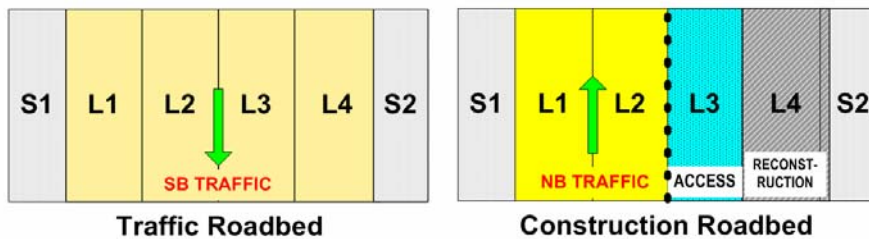
## Full Closure (Counter-flow Traffic) PCC Concurrent Double-lane Rehabilitation



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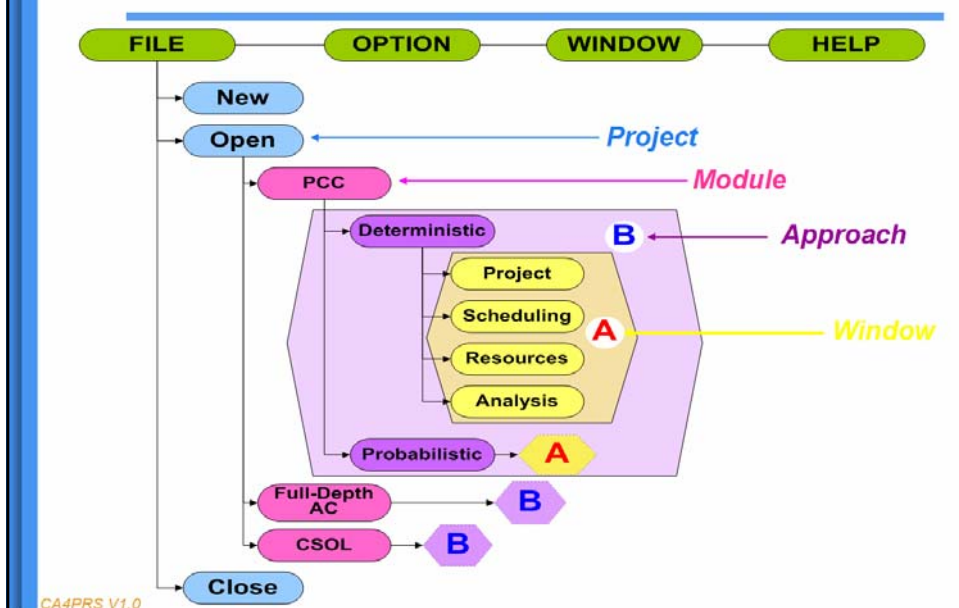
## Half or Partial Closure PCC Sequential Single-lane Rehabilitation



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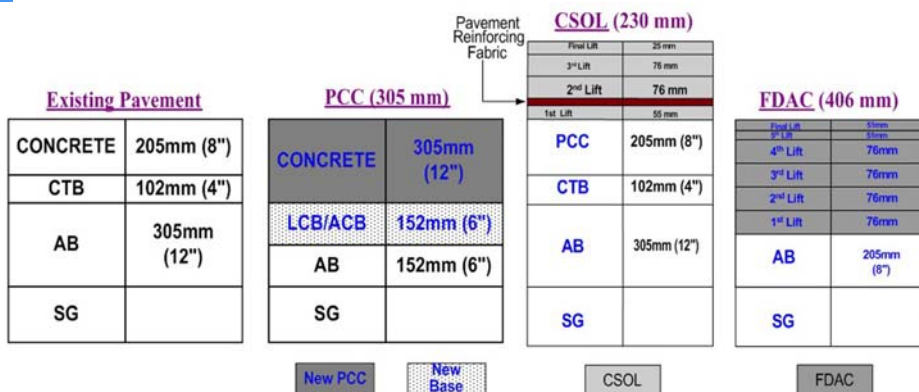
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## CA4PRS Software Menu Tree



## Major Caltrans Rehabilitation Strategies Modeled in CA4PRS

1. PCC (Concrete) Reconstruction
2. Crack-Seat AC Overlay
3. Full-depth AC Replacement



## CA4PRS Input (2): Resources

Project Identifier: I-15 Concurrent (Prob)

Project Details | **Scheduling** | Resource Profile | Analysis

**Dump Truck (Demolition)**

Rated Capacity (kg): 22000.0

Trucks per Hour: 10.0 ☒

Packing Efficiency: 0.65 ☒

Number of Team: 2.0 ☐

Team Efficiency: 0.75 ☒

**Batch Plant**

Capacity (cu. m): 150.0 ☒

Number of Plants: 1

**End Dump Truck (New Base)**

Capacity (cu. m): 10.0 ☐

Trucks per Hour: 4 ☒

Packing Efficiency: 1.00 ☐

**End Dump Truck (PCC)**

Capacity (cu. m): 6.0 ☐

Trucks per Hour: 11 ☒

Packing Efficiency: 0.90 ☐

Save

**Define Probability ...**

Probability Function: Normal

Mean: 10

Std. Dev.: 1

## CA4PRS Input (3): Schedule

File Options Window Help

**PCCP Probabilistic - I-15 72-H Weekday (Final)**

Project Identifier: I-15 72-H Weekday (Final)

Project Details | **Scheduling** | Resource Profile | Analysis

**Mobilization**

Mobilization (Hours): 3.0 ☒

Demobilization (Hours): 13.7 ☒

Construction Start Date: 3 / 1 / 2004

Construction Window...

**Lag Times for Sequential Working Method**

Demolition to New Base Installation (Hours): 14.0 ☒

PCCP Installation can begin before New Base Installation is Complete: ☐

New Base Installation to PCCP Installation (Hours): 6.0 ☒

**Lag Times for Concurrent Working Method**

Save

**Construction Window Settings**

**Weekend Closure**

Start Time on Friday: 10:00 PM

End Time on Monday: 05:00 AM

Available Hours: 55.0

**Nighttime Closure**

Start Time on First Day: 07:00 PM

End Time on Next Day: 05:00 AM

Available Hours per Day: 10.0

**Continuous Closure/Continuous Operation**

Start Time on First Day: 12:00 AM

No. of Continuous Work Days: 3.0

Available Hours per Day: 24.0

**Continuous Closure/Shift Operation**

Daily Start Time: 06:00 AM

No. of Continuous Work Days: 6.0

Available Hours per Day: 16.0

Save Close

# CA4PRS Input (4): Design & Traffic

Project Identifier: I-15 72-H Weekday (Final)

Project Details | Scheduling | Resource Profile | Analysis

Construction Window

- ☐ Weekend Closure
- ☐ Nighttime Closure
- ☒ Continuous Closure/Continuous Operation
- ☐ Continuous Closure/Shift Operation

Curing Time

- ☐ 4-Hours
- ☐ 8-Hours
- ☒ 12-Hours
- ☐ User Defined  Hours

Working Method

- ☐ Sequential Single Lane (T1)
- ☐ Sequential Single Lane (T2)

Section Profile

- ☐ 203 mm (8 inches)
- ☐ 254 mm (10 inches)
- ☐ 305 mm (12 inches)
- ☒ User Defined PCCP (mm):  Treated Base (mm):  Additional Demolition Depth (mm):

Analyze... Compare...

Close

**Construction Plan**

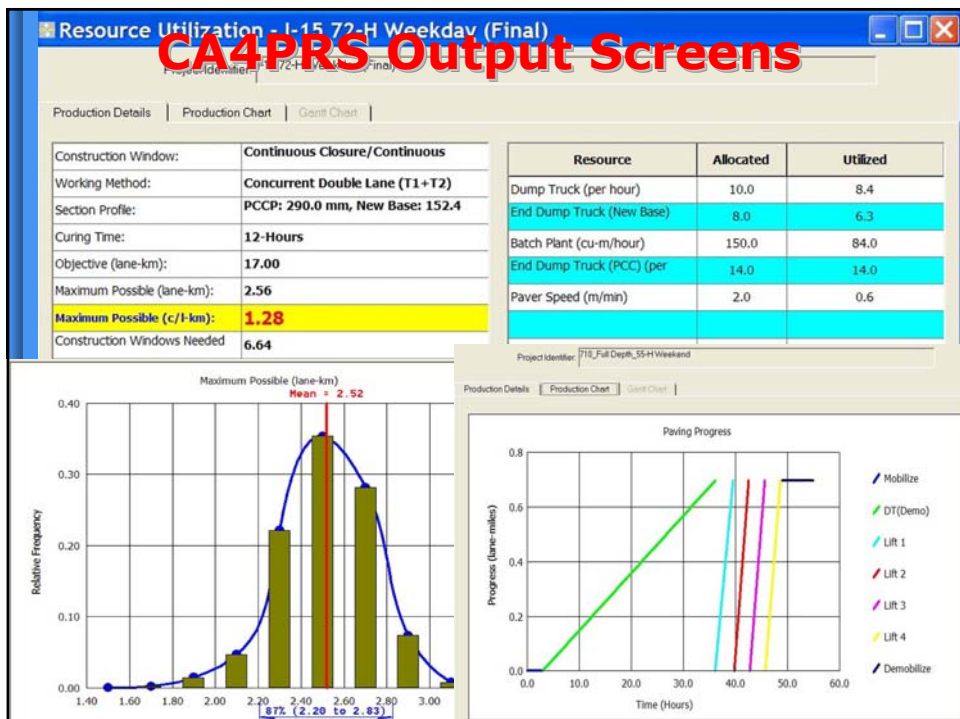
- ☒ Sequential Single Lane (T1)
- ☐ Sequential Single Lane (T2)
- ☐ Sequential Double Lane (T1+T2)
- ☐ Concurrent Single Lane (T1)
- ☐ Concurrent Single Lane (T2)
- ☐ Concurrent Double Lane (T1+T2)

Construction Plan

Open Access Paving

Close

# CA4PRS Output Screens



Microsoft Excel - RUC Estimation\_031604

# Demand-Capacity (HCM) Spreadsheet

**DEMAND-CAPACITY MODEL (Highway Capacity Manual)**

Traffic Demand Input

Demands Input

Capacity Information

Capacity (Normal) 2100

Capacity (CWZ) 1500

Total Reduction(%)

No show up 5

Detour 5

Normal Information

Direction Eastbound

Number of Lanes 4

Speed Limit (MPH) 70

Vehicle Cost Input

Passenger Car (\$) 9

Commercial Truck (\$) 24

Proportion of Truck (%) 10

CWZ Information

Number of Lanes open on CWZ 2

Speed Limit on CWZ (MPH) 50

Length of CWZ (mile) 2

Number of Closures 8

Closure Duration(days) 3

Lane Closure Period Setting

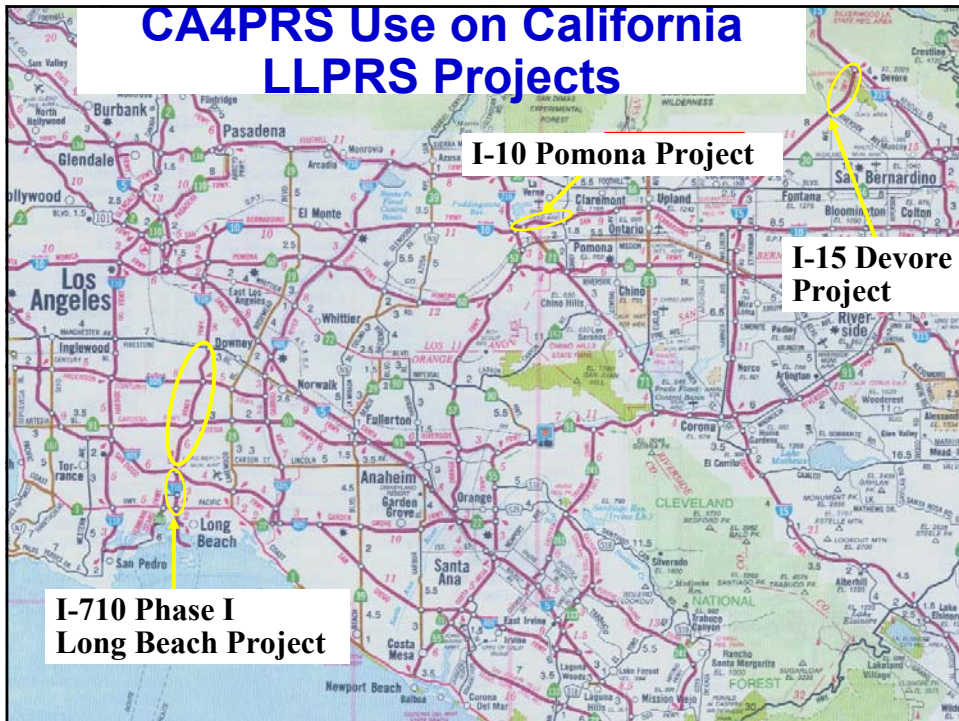
OK Cancel

# CA4PRS Pilot Projects

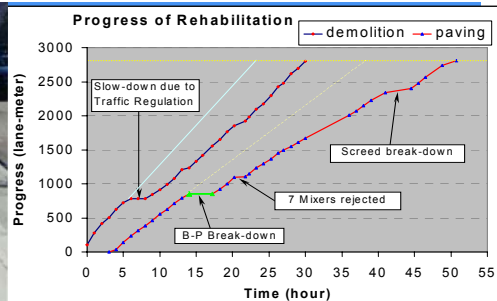
- I-10 Pomona (D7): FSHCC
- I-710 Long Beach (D7): AC
- I-15 Devore (D8): 12-hour PCC



# CA4PRS Use on California LLPRS Projects



## I-10 Pomona Project CA4PRS Verification



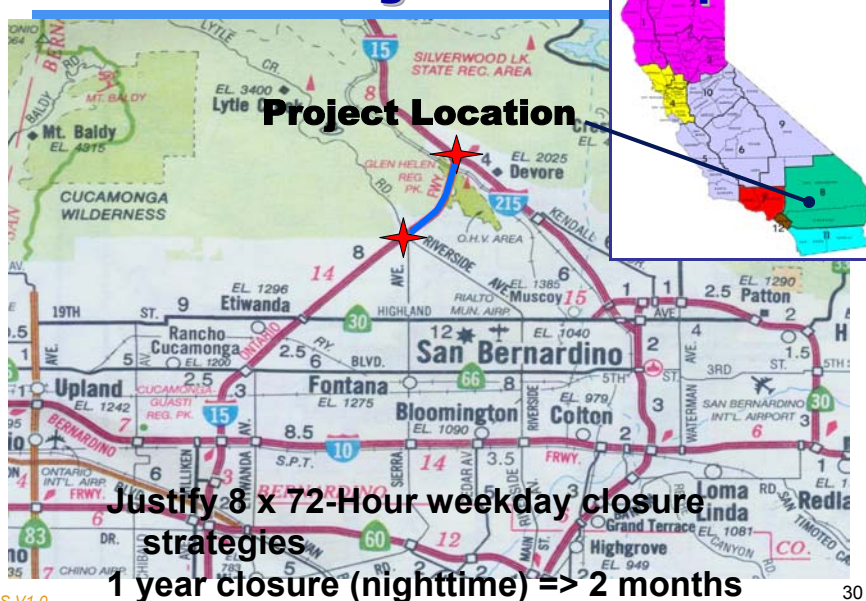
### 55-hour Weekend Production

- Contractor's Plan = 3.5 lane-km
- CA4PRS Estimate = 2.9 lane-km (2.4-3.4)
- Actual Performance = 2.8 lane-km

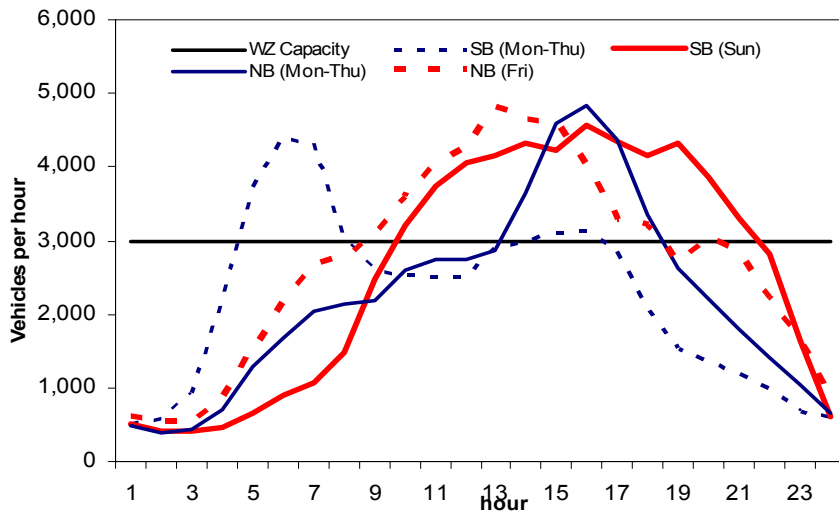
## I-710 Long Beach project CA4PRS Recommended to Revise the Contractor's Staging Plan



## I-15 Devore Project CA4PRS Integration Example



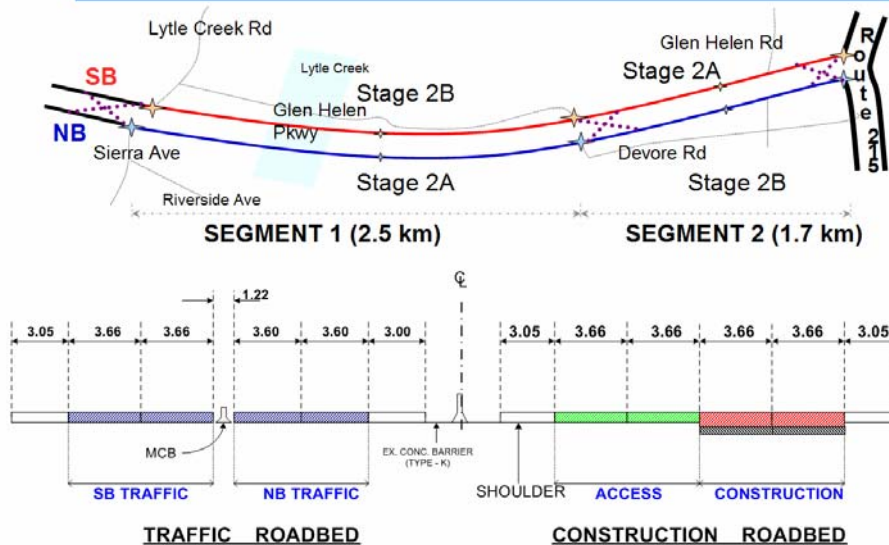
# I-15 Devore: Daily Traffic Patterns



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## Stage Construction Scheme (Full Closure: Counter-flow Traffic)



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## I-15 Devore Concrete Pavement Cross-section Changes

- 200mm PCC with 100mm CTB => 300mm PCC with 150mm AC Base
- Early-Age Strength Type III PCC (400 psi (f) in 12-H)

CONCRETE	205mm (8")	➔	12-H Type III CONCRETE	290mm (11.5")
CTB	102mm (4")		AC Base	152mm (6")
AB	305mm (12")		AB	152mm (6")
SG			SG	

Old Section		New Section	
Removed	Retained	New PCC	New Base

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## I-15 Devore: Construction Scenarios Evaluated

- **Basic: Construction Windows**
  - 72-Hour Weekday Closures
  - 55-Hour Weekend Closures
  - 1 Roadbed Continuous Closures
  - 10-Hour Night-time Closures
- **Constructability Reviews**
  - Variation of 72-Hour Weekday Closures
  - Mix Design: 12-Hour Type III vs. FSHCC
  - Base Type: Lean-concrete vs. AC Base
  - Widened truck lane vs. Tied-shoulder

RETE 205m

TB 102m

AB 305m

SG

## I-15 Devore: Schedule Comparison CA4PRS Analysis Results

	Construction Scenario	Total Closures	Total Closure Hours	%
(2)	72-Hour Weekday	8	512	100%
(3)	55-Hour Weekend	10	550	110%
(1)	1 Roadbed Continuous	2	400	78%
(4)	10-Hour Night-time	220	2,200	430%

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## I-15 Devore Selected the Most Economical Scenario: Schedule, Traffic Delay, Total Costs

Construction Scenario	Schedule Comparison		Cost Comparison (\$M)			Max. Peak Delay (Min)
	Total Closures	Closure Hours	User Delay	Agency Cost	Total Cost	
★ 72-Hour Weekday Continuous	8	512	5.6	12.6	18.2	75
55-Hour Weekend Continuous	10	550	14.2	15.1	29.3	195
1 Roadbed Continuous	2	400	6.9	9.9	16.8	195
10-Hour Night-time Closures	220	2,200	4.9	20.4	25.3	35

**Lane Closure Review Committee Approved  
72-Hour Weekday Closures (March 2003)**

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## **I-15 Devore Budget Reality Check Downsize Rehab. Scope with CA4PRS**

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- **Result of the First Bids (2003 Fall)**
  - Estimate (\$12M) vs. Lowest (\$21M)
    - *Mainly Due to High Traffic Control Costs*
  - Construction schedule (2004 Spring => Fall)
- **Impact on Rehabilitation Scope**
  - Project Scope Reduction: Budget Constrained
  - Only Outer truck-lane Reconstruction
  - Inner truck-lane: Random Slab Replacement
- **Revised Scenario Analysis**
  - Selected Full-closure compared to Half-closure
  - CA4PRS Estimated 6 x 3- or 4-day Closures

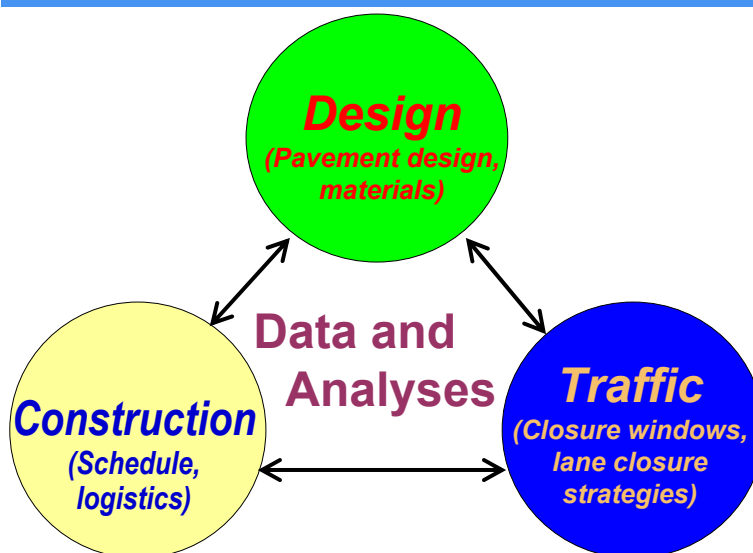
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## **CA4PRS Deployment Efforts**

## Candidate Projects for the CA4PRS Implementation

- Long-life Pavement Rehabilitation
- Accelerated Construction with Round-the-clock Operations
- High-profile Pavement Rehabilitation with Heavy Traffic in Urban Environment
- Public Outreach Needed Project
- Project Size: Minimum \$X Millions
- Cycle: Planning => Design => Construction
- Lessons Learned Data : during construction

## CA4PRS Facilitates Integration of District User-Group Teams



## Who Uses CA4PRS?

- Training Workshops: 4-state Fund
  - Caltrans Materials Academy: 4-hour class (D8) - 2003
  - 4-DOT x 2 Workshops: 1-day class (D8/D7) - 2003
  - Training for In-state Trainers: 4-day (D3/HQ) – 2004
- 4-State CA4PRS Experiences
  - CA: I-10, I-710, and I-15
  - MN (I-35), TX (Pegasus), WA (I-5)
- American Concrete Pavement Association (ACPA) distributes CA4PRS
- NAPA is Considering to distribute CA4PRS

## CA4PRS Outreach DRI and PPRC Efforts

- In-house Outreach: DRI Website
  - Detail information available
  - Software downloadable
- Public Outreach
  - Brochure and Poster
  - TR News Articles
  - Reports and Journal papers
  - ACPA & NAPA: Conferences, Magazines
- Training for Caltrans
  - Some training performed
  - Need to identify Caltrans users and transfer use to Caltrans

## **Recommended CA4PRS Training**

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- Recommend 2-day Hand-on Training Class
  - 10-15 Trainees per Class
  - Need Computer Lab Facility
  - Need Fund Supports
  - Technology Transfer Program
- Who Should be Recommend for Training
  - D3, D4, D6, D7, D8, D11, D12
  - Target: Design/Construction/Traffic Engineers
- Needs HQ Coordination
  - Present to District Division Chief Meetings
  - Introduction to District Level

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## **CA4PRS Enhancement and Upgrade (PPRC and 4-State Supports)**

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- V1.0 Traffic Analyses handled separately
  - PRC Developed a HCM Spreadsheet
- V1.5-a: Userability & Interface Improvement
  - Develop the Manual
  - Improve Userability
- V1.5-b: Add more Rehabilitation Strategies
  - Mill & fill AC Rehabilitation
  - CRCP Rehabilitation
- V2.0: Traffic Analysis (Road User Cost)
  - Demand–Capacity Model (Highway Capacity Manual)
  - Economic analysis (RUC + Agency Cost)

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# Discussion

## **Needed HQ Support for CA4PRS Deployment**

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- **Support for Training**
  - **Budget required**
  - **Introduction to Major Districts**
- **Implementation to District Level**
- **More Case Studies for Implementation**
- **Maintenance and Technical support**
- **Enhancement**

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# CA4PRS

## Additional Information

### **I-15 Devore: Traffic Analysis Models Integrated with CA4PRS**

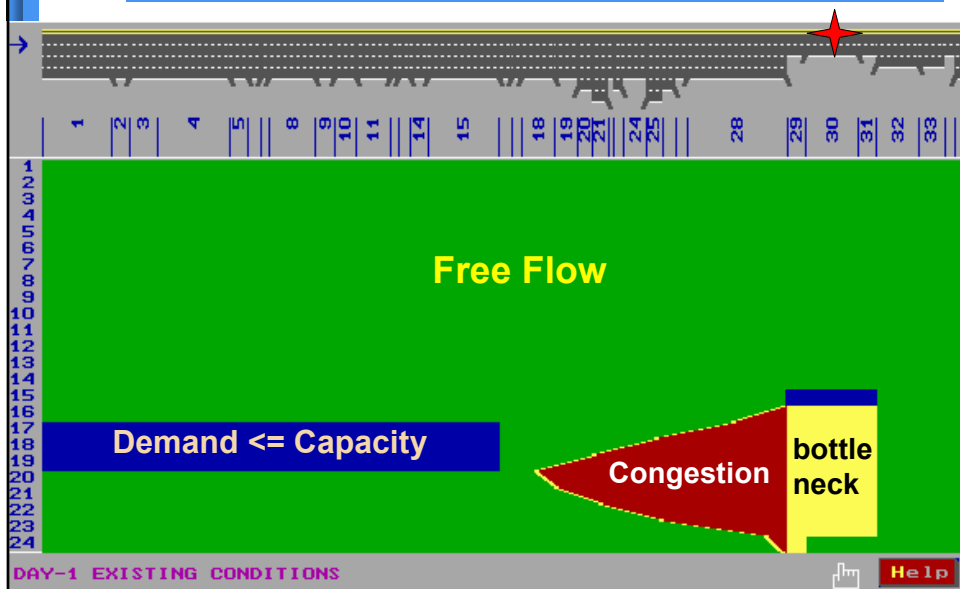
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- **Step 1: Demand-Capacity Model (HCM)**
  - Road user cost: Compare all scenarios
  - Select the most economical scenario: Total cost
  - Sensitivity for TMP (Demand reduction, CWZ capacity)
- **Step 2: Macro Traffic Simulation (FREQ)**
  - Focus on the Selected Construction Scenario
  - Baseline for Incentives/disincentives and A+B contract
  - Develop lane closure charts
- **Step 3: Microscopic Simulation (PARAMICS)**
  - Blocking Freeway Connector: I-210 to I-15 NB
  - Truck restriction during peak hours through CWZ
  - Relocate the junction split location



# FREQ Macro-simulation

## Segment 1 Northbound Closure (NB traffic)



## Paramics: Macroscopic Simulation Model

